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ATLAS TRT Barrel Electronics Cooling: When electronics at one end are turned off

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This is a supplement to a previous note (DUKEHEP00-03-1) to address the question regarding the thermal impact when electronics on one side of a module are turned off.

Figures 1 and 2 show temperature distributions inside the module when electronics on both sides of a module are operational. The FEA calculation assumes symmetry of the module and only one half of the module is simulated. The boundary conditions of this model assume the cooling fluid flows through the electronics first and then the module, as described in DUKEHEP00-03-1, thus:

- Cooling tube temperature for the module cooling fixed at 20°C.
- Tension plate temperature fixed at 30°C.

When one side of the electronics is turned off, two things happen:

1. One of the tension plates will be at nearly the cooling fluid temperature, ~15°C.
2. One of the 2 cooling tubes for module cooling will be at a lower temperature, ~15°C, because it doesn't pick up any heat from electronics, while the other will stay at ~20°C.

Here, we will try to address the following 2 questions:

1. How does the temperature on one end of a module influence the temperature on the other side of the module?
2. How does the asymmetry of the module cooling tube temperatures affect the temperature distributions inside the module?

Without making a new model, we ran the FEA program under the following new boundary conditions:

- One cooling tube temperature fixed at 20°C.
- The other cooling tube temperature fixed at 15°C.
- Both tension plate temperatures fixed at 30°C.

The results are shown in figures 3 and 4. These conditions would simulate the “on” side of a module when one end of the electronics is turned off. Except that the temperature distributions are slightly higher than what they should be, because the tension plate at the “off” side is also fixed at 30°C due to symmetry in our FEA model.

A comparison to this is to fix the tension plates at the “off” temperature:

- One cooling tube temperature fixed at 20°C.
- The other cooling tube temperature fixed at 15°C.
- Tension plate temperature fixed at 15°C.

The results are shown in figures 5 and 6. These conditions would simulate the “off” side of the module, except that the temperature distributions are slightly lower that what they should be because the tension plate at the “on” side is also fixed at 15°C.

Comparison of figures 3 and 5 tells us how well the two cases above simulate the “on” and “off” side of a module when one side of the electronics is turned off. With the symmetry in our FEA model, the real temperature distributions at the middle of the module should be just the average of figures 3 and 5. The comparison shows that the temperature differences between figures 3 and 5 are ~1°C or less. Thus, the deviation of the two cases above, half of the difference, is ~0.5°C. From this, we also conclude that the two tension plates are very much thermally isolated, because changing tension plate temperatures by 15°C only results in ~1°C or less changes at the middle of the module.

Comparison of figures 1,2 and figures 3,4 show us how the asymmetry of the cooling tube temperatures affects the temperature distribution in the module. Figure 2 shows that in the normal case the temperature variation across the module is ~11°C (20°C→31°C) when the electronics at both ends are on. Figure 4 shows that with the two cooling tubes at different temperatures the temperature variation across the module has increased to ~15°C (15°C→30°C). However, we note that most of the extra temperature gradient (15°C→20°C) is very concentrated near the cooling tube and most of the straws are still in the 20°C→30°C region as in the normal case.

Conclusions:

1. Temperature change at one end of the module (tension plate) has very little impact to the temperature on the other side (half) of the module.
2. Asymmetry in module cooling creates an extra temperature gradient of ~ 4°C. This extra gradient is concentrated near the lower cooling tube. The temperature variation across the module has increased from ~11°C to ~15°C.

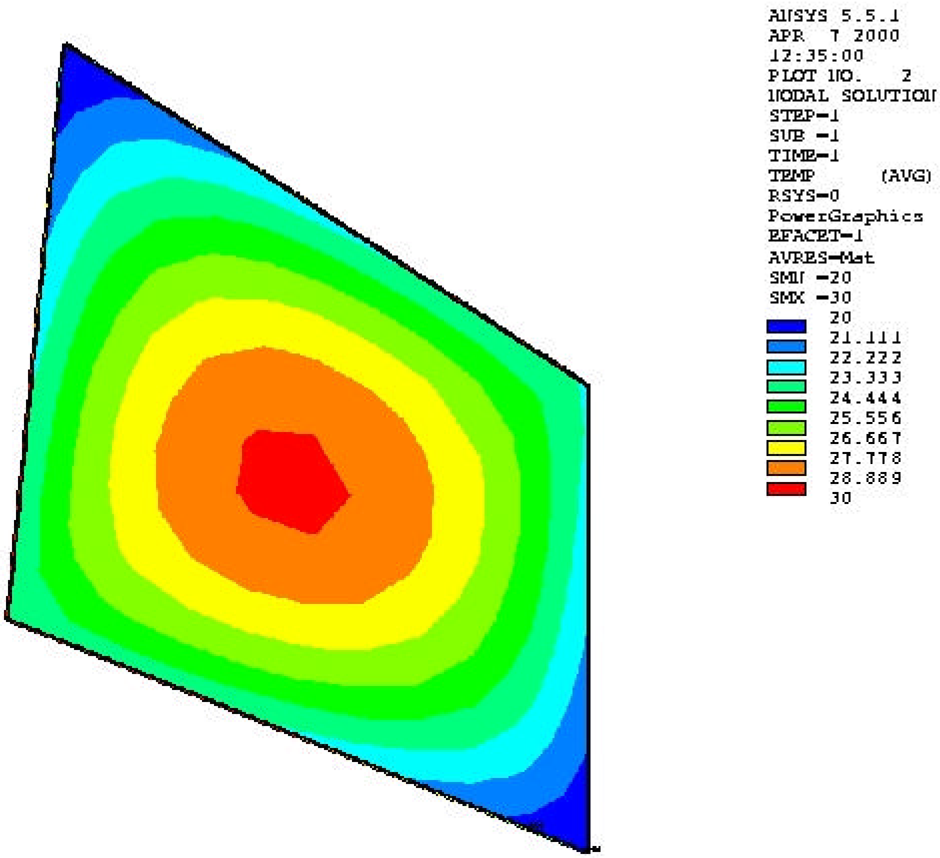

Figure 1. Tension plate = 30°C, cooling tube = 20°C, cross-section at middle of module

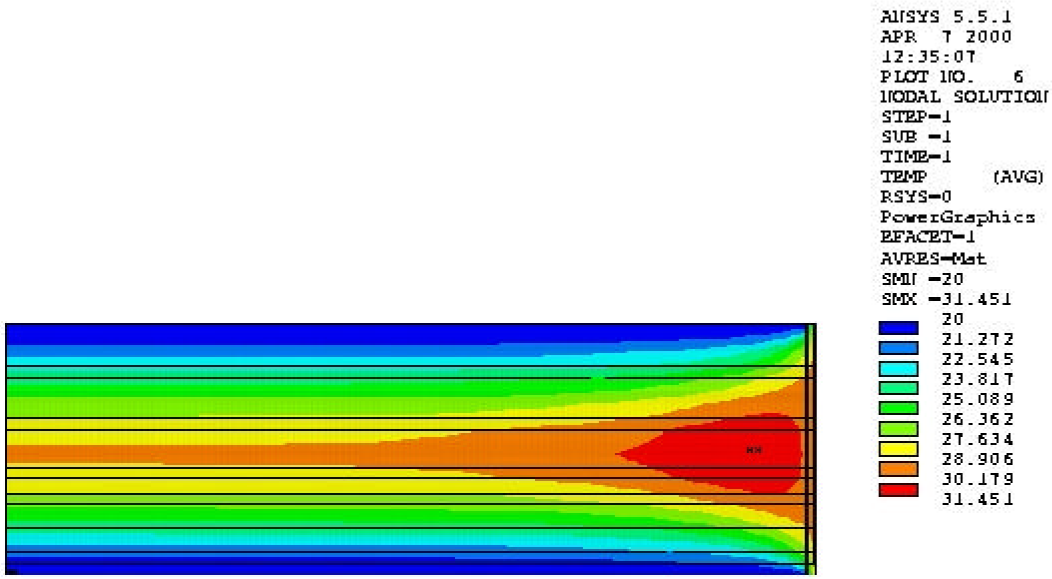

Figure 2. Tension plate = 30°C, cooling tube = 20°C, center slice of half module

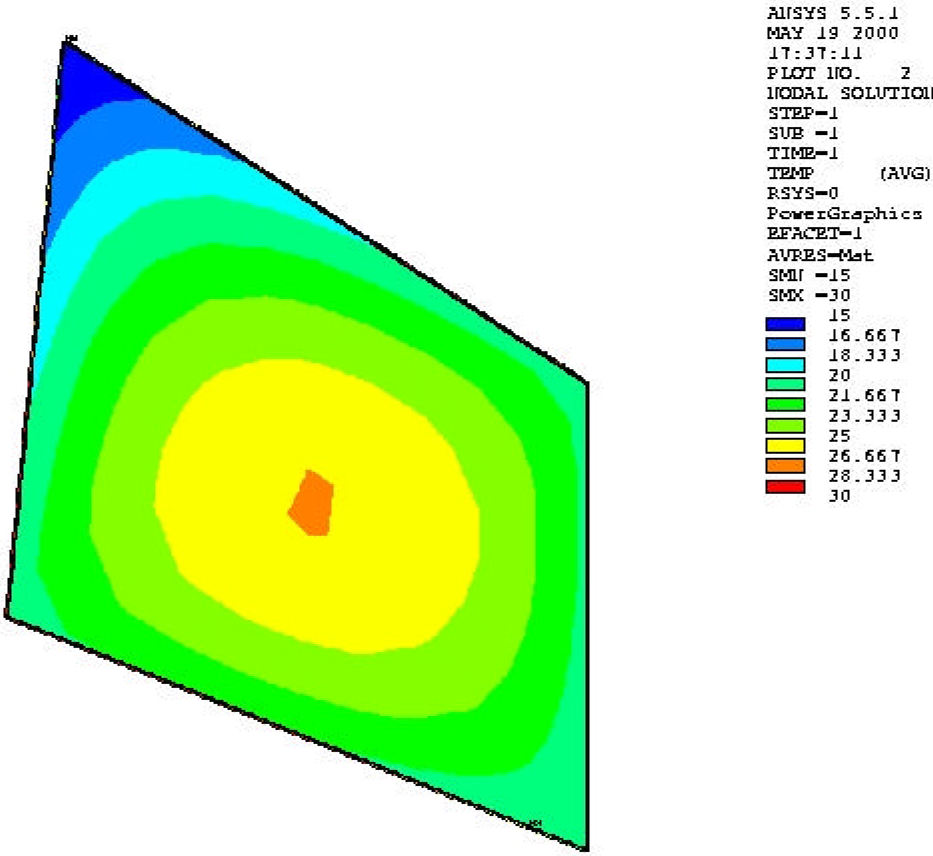

Figure 3. Tension plate = 30°C, cooling tube = 20°C & 15°C, cross section at middle of module

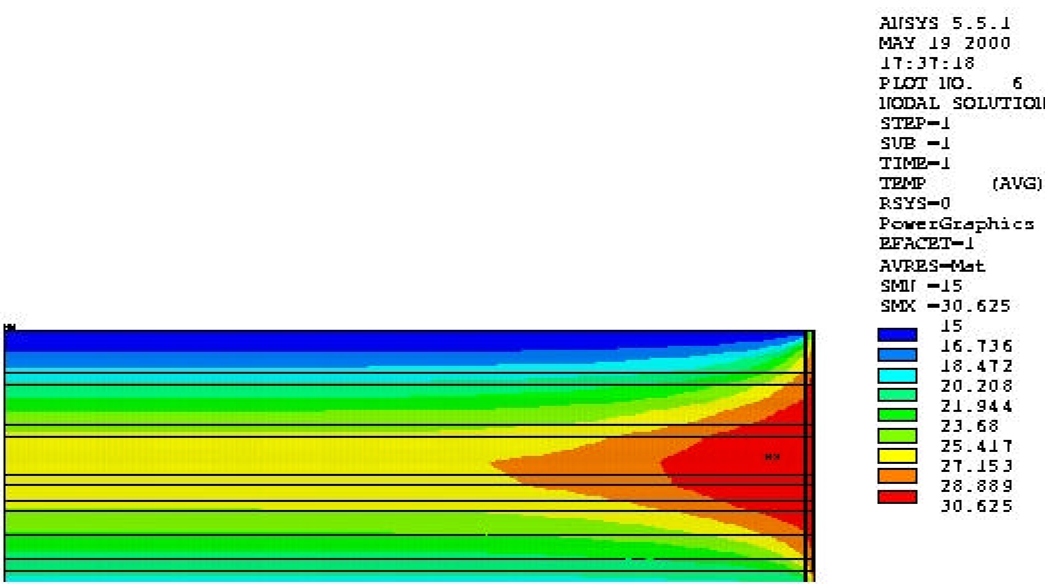

Figure 4. Tension plate = 30°C, Cooling tube = 20°C & 15°C, center slice of half module

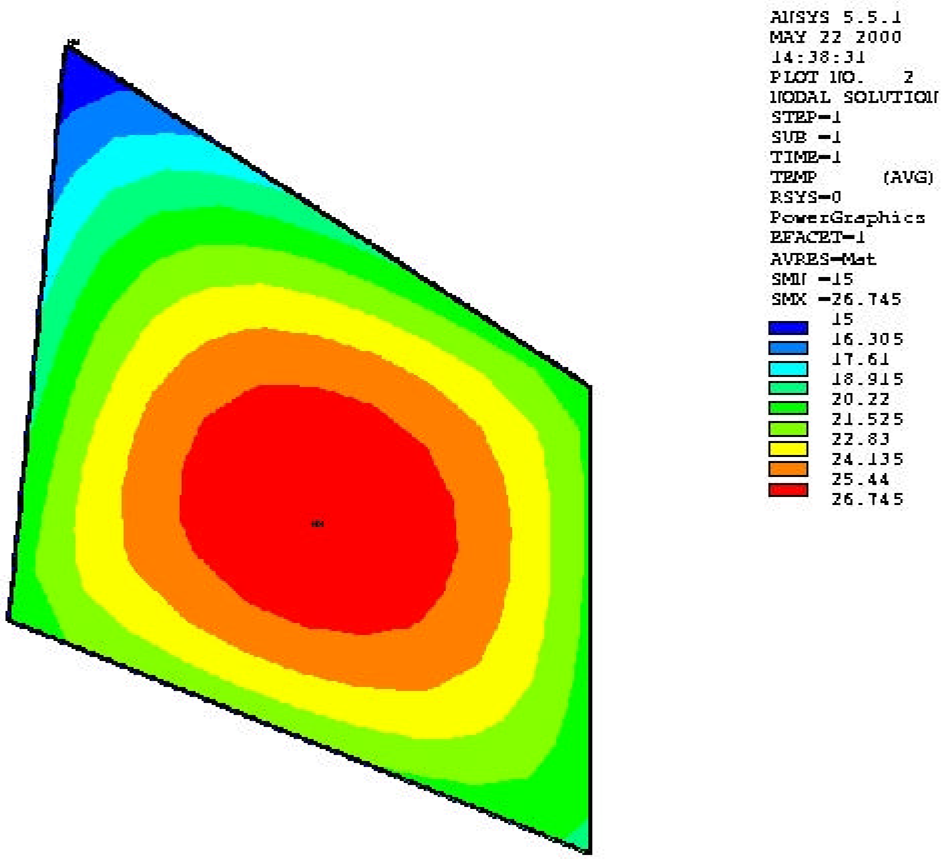

Figure 5. Tension plate = 15°C, cooling tube = 20°C & 15°C, cross section at middle of module

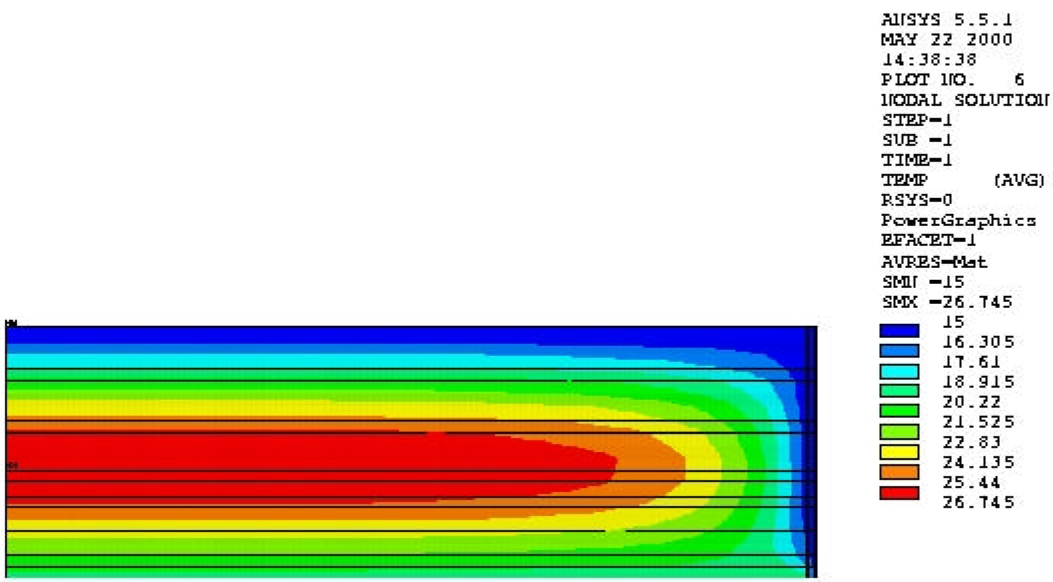

Figure 6. Tension plate = 15°C, Cooling tube = 20°C & 15°C, center slice of half module